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Articles PAGE

Variable Stars in the Globular Cluster N.G.C. 6402 ..... *Helen B. Sawyer* 57
Gamma Cassiopeiae ..... *J. F. Heard* 60
Telescope Mountings for Amateur Builders [III] ..... *H. Boyd Brydon* 63
The Physical State of the Upper Atmosphere (Conclusion) ..... *B. Haurwitz* 76

Meteor News

A Call for Volunteers to Observe Telescopic Meteors—Observations of the Leonids in 1936 ..... *P.M.M.* 93

Review of Publications

The Moon with Naked Eye and Field Glasses, by Calvin N. Joyner ..... *F.S.H.* 97

Notes and Queries

What Kind of Universe is it?—A World Famous Journal—A Catalogue of Simple Instruments ..... *C.A.C.* 98

Meetings of the Society

At Victoria—At Vancouver—At Toronto 100

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VARIABLE STARS IN THE GLOBULAR CLUSTER N.G.C. 6402*

By Helen B. Sawyer

THIS paper is a preliminary report on the variables in this cluster, as the work of period determination is far from complete. The cluster N.G.C. 6402 (Messier 14) lies in the constellation of Ophiuchus. The brightest stars are of the fifteenth magnitude, the cluster type variables of the sixteenth. The distance as determined in 1929 from the bright stars and integrated magnitude and diameter was 19.7 kiloparsecs.

Before 1932 no variable stars were known in this cluster, but an intensive search of plates taken at the Dominion Astrophysical Observatory revealed the presence of seventy variables, one of which was an outstandingly bright star in the cluster, and several were brighter than average. Eighty-three plates are now available, 31 from the Dominion Astrophysical Observatory, 48 from the David Dunlap, and 4 taken by Dr. Shapley at Mt. Wilson, and the variables have been estimated on all of these. However, the cluster is thickly populated with stars, and for fully half the variables only plates taken under exceptionally good seeing conditions can yield reliable estimates. It is expected therefore that to determine the periods of all the variables in the cluster will be an exceptionally difficult task, and will probably require the plates of several additional seasons.

A dozen periods have been determined thus far. The importance of these lies primarily in the fact that three of these variables are long period Cepheids, with periods of 18.75, 13.57, and 2.7952 days. The only globular clusters which have as many long period Cepheids

*Paper presented at the meeting of the American Astronomical Society, December, 1936.

are Omega Centauri and Messier 2, with five and four respectively. Three long period Cepheids lie in the region of N.G.C. 362, but these are accepted as members of the Small Magellanic Cloud. The three Cepheids in N.G.C. 6402 with mean magnitudes of 15.1, 15.6 and 15.8 follow in general a period-luminosity relation, though the slope of the curve is not so steep as that shown by Shapley's curve determined from more points. There is a possibility of some error in estimating the magnitudes of the brighter variables, as the plates were taken to show stars of magnitude 17.5, and the images of stars of the fifteenth magnitude are not best adapted to estimation on the reflector plates. Nevertheless it is difficult to see how the magnitudes of the brighter stars could be too faint by three-quarters of a magnitude, the amount by which the thirteen-day and eighteen-day Cepheids deviate from the curve. The sequence magnitudes were determined from six plates taken with a double exposure on the cluster and a standard magnitude region. One plate from the Dominion Astrophysical Observatory and two from the David Dunlap have Kapteyn Area 109 as comparison. Three taken by Dr. Shapley at Mt. Wilson have the north polar sequence. The magnitudes of the cluster sequence as determined from the different plates agree very well, despite a wide range in image texture due to different seeing conditions for the different plates. Apparently the discrepancy cannot be explained by an error in the period-length; submultiples of the accepted periods have been tried, and do not satisfy the points. The 83 observations are on 42 nights, and it is felt that the periods must be reasonably correct. Of course there is the possibility that these two Cepheids may not be connected with the cluster at all, but actually belong to the galactic system beyond the cluster. The chance of this occurring for two Cepheids in a twentieth of a square degree at galactic latitude $+15°$ is not large, but it is not negligible. Until the investigation of this cluster is completed, we may say that qualitatively these Cepheids show the period-luminosity relation, but quantitatively they do not meet it exactly.

Nine periods have been determined for cluster type variables. They appear normal in all respects; the periods thus far determined range from 0.55 to 0.60 day. It is expected that practically all of the variables in this cluster will prove to be short-period Cepheids. There are several rather bright variables, however, which may be

the irregular type such as Baade has found in N.G.C. 2419. Few if any of the remaining variables, as judged from an inspection of the estimates, will prove to be long period Cepheids.

There would appear to be considerable evidence that this cluster is very strongly obscured. It happens that the writer is working simultaneously on the variables in two globular clusters which present a study in contrasts. N.G.C. 6934 is a small cluster situated in the constellation of Delphinus, galactic longitude 20° and latitude –20°, a position 55° from the galactic center. The cluster is very rich in variables, for it contains fifty, all of them apparently cluster type. The diameter of N.G.C. 6402 is nearly twice that of N.G.C. 6934. But the striking thing is that the cluster type variables are *fainter* in N.G.C. 6402 than in N.G.C. 6934. The mean magnitude of 46 cluster type variables in N.G.C. 6934 is 16.67; the mean magnitude of 61 in N.G.C. 6402 is 16.85. Stebbins has found a rather red colour index for this latter cluster, +0.12, practically equivalent to K0 on his scale, whereas N.G.C. 6934 has a negative colour index of –0.04. If we make the assumptions that all globular clusters have the same linear diameter and the absolute magnitude of the cluster type variables is the same from cluster to cluster, both of which are reasonable working hypotheses, we can compute the absorption in the region of N.G.C. 6402 *relative* to that in the region of N.G.C. 6934, and we find a difference in absorption between these two regions of one magnitude. The large absorption in the region of N.G.C. 6402, longitude 349°, latitude +14° would appear to be largely an effect of longtitude, since its latitude is similar to that of N.G.C. 6934 (–20°). This would appear to be an interesting example of the differences in absorption to be expected between different regions of the sky. This absorption of a magnitude would reduce the 1929 distance by a factor of a third to 12 kiloparsecs. However, the modulus as determined from my observations is 0.3 magnitude fainter than the earlier one. But Hubble's cosecant law gives a value of the general absorption in the region of N.G.C. 6934 as 0.26 magnitude, a general correction to be applied, which as it happens, about balances the revision of the modulus. We may therefore consider twelve kiloparsecs a fair estimate of the distance of the cluster based upon the foregoing assumptions.

David Dunlap Observatory,
December, 1936

GAMMA CASSIOPEIAE

By J. F. HEARD

DURING 1936 the familiar star, γCassiopeiae, came into some prominence owing to unprecedented variations in its brightness. Apparently P. Baize[1] was the first to notice an increase in brightness, on July 25, which amounted to three-tenths of a magnitude. Since then considerable variation, as much as half a magnitude and apparently of an irregular character, has been observed.

Any changes in the spectrum of this star concurrent with the changes in its brightness will be of interest, as they may possibly lead to an interpretation of the variations in its light.

Since December, 1935, a number of spectrograms of γCassiopeiae have been obtained at the David Dunlap Observatory, using the one-prism spectrograph fitted with the 25-inch camera lens which gives a dispersion of about 33 A/mm. at Hγ. The spectrograms have been made on Eastman Process emulsion to give a high degree of contrast. Examination of these plates has revealed a number of interesting spectrum variations, some of which have already been reported by D. B. McLaughlin[2], who has discussed certain changes which took place up till May, 1936.

In 1935, Lockyer[3] announced the appearance of a strong absorption line of He I at λ3889. The appearance of this line was followed late in 1935 and early in 1936 by marked increase in intensity of other He I absorption lines. This absorption spectrum of He I increased in intensity until June. Since the beginning of 1936 the stronger of the He I lines have been accompanied by emission components on either side. From August until December the He I absorption spectrum has faded, while the He I emission components have been enhanced, so that on the plates taken in December the He I spectrum is essentially an emission spectrum.

Along with this change the hydrogen spectrum and the ionized iron spectrum have exhibited changes. Normally, in the spectrum of γCassiopeiae, the H lines and Fe II lines have shown two emission components of approximately equal intensity with a doublet separ-

[1] *L'Astronomie*, August, 1936.
[2] *Ap. J.*, v. 84, p. 235, 1936.
[3] *M.N.*, v. 96, p. 2, 1935.

ation of about 166 km./sec. Early in 1936 the separation of the components of both H and Fe II lines was about 200 km./sec., and the violet components were, generally speaking, somewhat fainter than the red. During the year there has been a general decrease in separation of the components of both H and Fe II lines accompanied by a general increase of intensity of the violet components over the red. These changes have been more marked for H lines than for Fe II lines; in December the separation of the H lines was about 110 km./sec. and of the Fe II lines about 135 km./sec.

The 1936 variations referred to in the two preceding paragraphs recall similar variations pointed out by the writer[4] for 1934. In the latter part of that year He I lines appeared strongly in emission and H and Fe II doublet separations decreased to 113 km./sec., but on that occasion the red components were much more intense than the violet, the relative intensities having reversed themselves since 1933.

Plates taken in November and December, 1936, show not only an enhancement of He I emission but also an enhancement of the emission spectrum generally, so that careful measurement of these plates has revealed lines not previously reported in the spectrum of γCassiopeiae. Among these the most interesting is Ca II 3933 which has appeared both in absorption and emission with increasing intensity during 1936.

A number of investigators of the spectrum of γCassiopeiae, notably Curtis, Lockyer, McLaughlin and Cleminshaw, have made reference to changes in the emission ratio (V/R, *i.e.* violet: red) of the H lines, and conspicuous inequalities have been recorded (both $V/R > 1$ and $V/R < 1$) based mostly upon estimates of Hγ and Hδ. These authors have not, however, specifically drawn attention to outstanding differences of V/R from one line to another. The series of plates referred to in this note show the doublets of Hβ, Hγ, Hδ, Hϵ, and sometimes several more, all well resolved; these show very clearly a decided increase of V/R toward higher series members. Visual estimates are not sufficient to reveal whether or not the magnitude of this increase of V/R is variable, but it seems probable that it is. Furthermore, V/R seems not to be the same for all Fe II lines and certainly it is not the same for Fe II lines as for He I lines.

[4] *Ap. J.*, v. 81, p. 341, 1935.

These facts indicate that any interpretation of the emission doublets cannot be on an entirely mechanical basis.

Certain fluctuations in emission and absorption velocities during 1936 have been noted. It remains to be seen if these can be connected with fluctuations in light.

More quantitative data concerning the points mentioned in this note are being obtained and these will be published from this observatory.

David Dunlap Observatory,
January, 1937.

TELESCOPE MOUNTINGS FOR AMATEUR BUILDERS

By H. Boyd Brydon

(Continued from January issue)

Drive mechanisms may be placed in four general classes depending on the method of operation:

1. Hand
2. Gravity
3. Clockwork
4. Electric motor

Classes 1 and 2 may be distinguished as intermittent drives and 3 and 4 as continuous drives. Excepting the first, the classes are not distinct. Clockwork is frequently used to control the speed of a gravity drive; nearly all clockwork drives are controlled by an inertia or gravity governor and electric motor drives are controlled by hand, gravity, clockwork or electricity, singly or in combination.

1. *Hand Drives*

The simplest hand drive consists of a string passing round the main drive wheel and wound up on a small spool by hand. Other hand drives are

(*a*) Tangent screw.

(*b*) Worm wheel.

The tangent screw (see the slow motions shown in Fig. 6), like its brother the worm is a long screw turning in fixed bearings. A nut, carried between jaws at the end of the tangent arm runs on this screw but as the nut is prevented from turning, it travels along the screw when that is turned and causes the tangent arm to rotate the sleeve on the polar axis.

Though perhaps simpler than a worm wheel drive, the tangent screw has two disadvantages:

1. The movement of the telescope is not constant for a given distance moved by the nut but decreases as the nut departs from the mid-position.

2. When the nut reaches the end of its travel, observing must be interrupted to return the nut to the start, necessitating resetting the telescope in right ascension. This occurs at intervals which cannot be longer than 1½ to 2 hours as the angle between the tangent arm and the screw becomes too small. Much of the force

of this objection can be removed by turning the nut to the beginning of its travel before starting a lengthy observation. It does not appreciably affect short observations, as in variable star work.

The worm wheel drive avoids these inconveniences and, as it is but little more difficult to construct, a tangent screw main drive is hardly warranted. Moreover a hand driven worm drive can be easily changed over for mechanical operation. As a slow motion device, however, the tangent screw is very satisfactory and is frequently used for that purpose (see Fig. 6).

As is well known, in the worm wheel drive, the long screw, the worm, engages in teeth cut across the edge of the worm wheel. Being held in fixed bearings, when the worm is rotated it drives the worm wheel around one tooth for each revolution it makes itself. The worm drive is the standard drive for all important telescopes.

2. *Gravity Drives*

In drives of this class, the prime mover is a weight suspended from a flexible metal cord or tape which passes around the main drive wheel as in the simple hand drive. The problem with these gravity drives is to control smoothly the extremely slow fall of the weight. With an 8-in. diameter main wheel, for example, the weight drops about one inch per hour. Several means have been used for control: a friction clamp on the cable or tape; supporting the weight on the rod of a piston in a cylinder containing oil, the escape of the oil from below the piston being controlled by a finely adjustable valve in a by-pass pipe between the two ends of the cylinder; by clockwork; and even by resting the weight on sand in a cylindrical container and controlling its fall by regulating the escape of the sand through a hole in the bottom of the cylinder. This device was actually used by Henry Draper.[15] The piston was a loose fit in a cylinder of 1½-in. diameter by 18-in. long. It was necessary to wash the sand thoroughly and heat it to redness to destroy all vegetable matter and dry it and then sift it to size the grains.

The oil filled cylinder is a fairly satisfactory device. It has been used with great success at the Norman Lockyer Observatory

[15] *Sci. Am. Supp.* No. 1545.

at Sidmouth for widening spectrograms.[16] Fig. 15 shows one form of this device. A flexible cable passes round the main drive wheel, thence over an idler pulley to an eye at the top end of the oil cylinder piston rod. The drive weight, sufficient to overcome the polar axis friction and develop a pressure of about 5 lbs. per sq. in. in the oil cylinder, is carried on the rod. The piston has a cup leather packing.

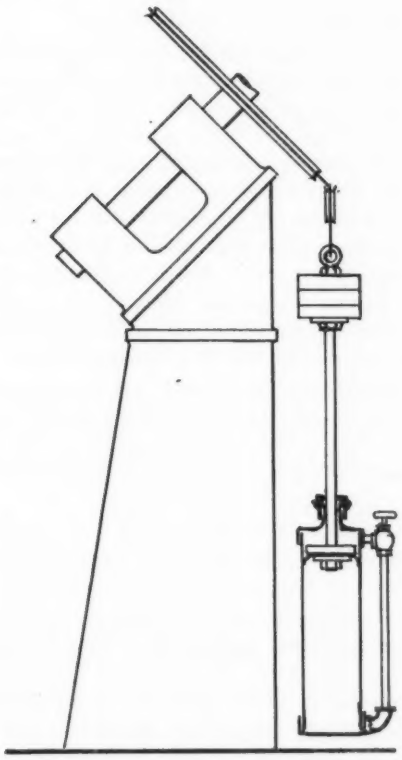

Fig. 15. Oil Cylindrical Control for Gravity Drive.

[16]Apparatus for broadening Spectra, W. J. S. Lockyer, *M.N.*, vol. 85, p. 47.

Where the moving parts are not too heavy, the clock controlled gravity drive is easily the best of the class. The idea, I believe, was first employed by F. J. Sellars, M.I. Mech.E. for driving a 3-in. refractor.[17] As used by Mr. Sellars the first or spring wheel gear of the clock engaged a rack mounted on a rod from which the driving weight was hung. The upper end of the rod was connected to a bell crank lever the arms of which were proportioned to the diameters of the main drive wheel and the clock wheel. This arrangement is indicated in Fig. 16.

Another way of using a clock to control the fall of the weights in a gravity drive is to pass a turn of the weight suspension cord around a pulley of suitable diameter mounted on an extension of the winding spindle of the clock, as indicated in Fig. 14. In a common type of alarm clock the winding spindle rotates once in 6 hours; thus the pulley diameter would be one quarter the diameter of the main drive wheel. The amount of drive weight is adjusted to be slightly greater than that needed to overcome the friction of the polar axis bearings, etc. It will be clear that the actual work of driving the telescope is done solely by the weight, the clock simply regulating its rate of fall, which can be further controlled by varying the position of the clock speed regulator. Recent tests by the writer indicate that for continuous runs of two to three hours a torque of 1.5 in.-lb. acting with or against the main spring (giving a range of 3 in.-lb.) is the maximum that can be applied safely for control purposes in this manner using a common 24 hr. "dollar alarm clock".

Where the moving parts are too heavy to be controlled by a clock alone, possibly the combination of an oil cylinder as in Fig. 15 with a clock for fine control might be found to be an adequate solution.

If carefully made and applied to a well balanced mounting offering little friction, the clock controlled drive appears to give reasonably successful service in careful hands for all but the exacting work of long exposure photography. It must be admitted however that drives of the intermittent kind as have been described are more or less make-shifts whose chief justification is their low cost.

[17] *J.B.A.A.*, April, 1930. See also *Amateur Telescope Making*, 4th ed., p. 275.

The well designed clock or electric motor drive is so much more accurate and convenient as to be well worth the additional trouble and expense involved.

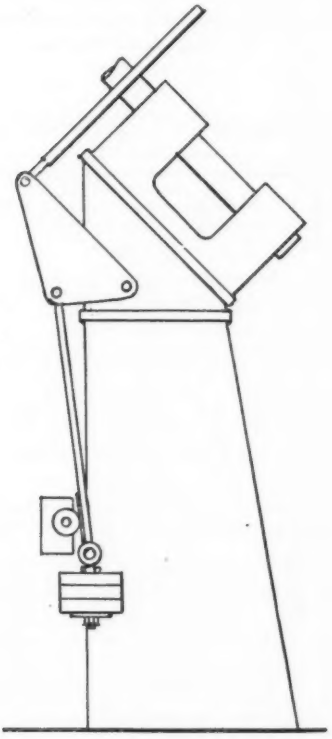

Fig. 16. Sellars Clock Control for Gravity Drive

3. *Clockwork Drives*

A typical form of clock for driving a telescope is shown in Fig. 17. It consists of a train of gears driven by a weight suspended from a cord wound on the barrel, but instead of an escapement, as in the ordinary timepiece, the speed is controlled by a fly-ball

governor. As the balls move outward when the speed increases, the upper ends of the governor arms are raised, pressing them against a friction plate whose vertical position is adjustable. Thus the motion is continuous instead of step by step as in the common clock. Motion is transmitted to the main worm on the telescope mounting by two pairs of bevel gears the lower pair being shown.

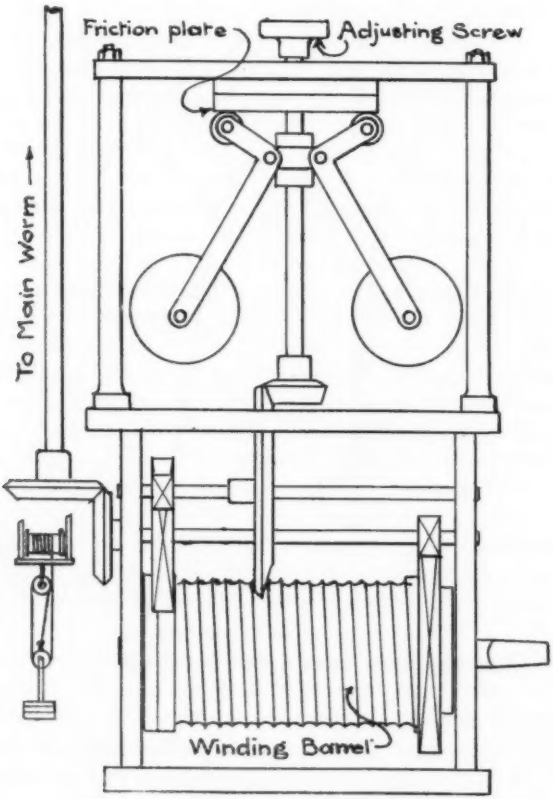

Fig. 17. Typical Driving Clock.

Worm wheel drives are generally preferable for such positions because of the liability to periodic error with bevel gears.

The small sketch at the left lower corner of Fig. 17 shows a common method of reeving the weight cord to reduce the gear ratio in the drive and prolong the period between re-windings.

4. *Electric Motor Drives*

Three general types of electric motor are available for driving a telescope:

Synchronous.....squirrel cage rotor
Induction.....wound rotor
Universal.....series wound

All squirrel cage motors have a low starting torque. The wound rotor is far superior in this respect but is slightly more expensive.

The speed of synchronous and induction motors depends upon the frequency of the supply current, usually 60 cycles per second throughout North America. The available speeds are high. Synchronous motors run at 3600, 1800, 1200 r.p.m.; induction motors at speeds which are a few per cent. lower than these "synchronous" speeds, varying slightly with the size of motor and the load at which it is operating. Universal motors run at still higher speeds. They are made up to 1/3 H.P. to run at from 5000 to 15000 r.p.m. Thus when driving an astronomical telescope the speed reduction required is of the order of some millions to one, but these great reductions are easily obtained by using worm reduction gears.

All these motors are available with self starting devices built into them and are designed not to interfere with radio reception.

Except for the very small motors used in electric clocks, etc., the synchronous motor must be supplied with direct current for field excitation. Apart from this, the use of a synchronous motor to drive a telescope is of questionable advantage as its speed under all conditions is the speed of the power supply. If the power station runs exactly at a frequency of 60 cycles per second of civil time, so will the synchronous motor. If the power station frequency, as it easily may, varies for short periods by a cycle or so up or

down, so also will the speed of the motor.[18] As these departures from standard frequency usually will not exceed a temporary loss or gain of over a minute or two and will balance out in the course of a few hours the synchronous motor fulfils the requirements of ordinary time keeping but by itself it cannot be depended upon to hold a telescope exactly on a star. Even when the necessary gearing is introduced to correct for the difference of about ten seconds per hour between civil and sidereal time and in regions where frequency is continuously and precisely controlled some means for adjusting the movement of the telescope will be found as necessary or at least as desirable as when an ordinary induction motor is used. Under a given load there is in fact little or no difference in constancy of speed between the two motors, while the induction motor has the important advantage that its speed can be maintained constant notwithstanding slight changes in the frequency of the supply current by using a pendulum speed control as in the Gerrish drive. The advantage then seems rather to lie with the induction motor in this respect.

The universal type of motor commonly used for sewing machines and other domestic appliances is a series wound motor with similar characteristics to the direct current series motor, high starting torque and rather wide speed variation from no load to full load. With a reasonably constant load, however, the speed of these motors can be varied over a wide range by inserting resistance in the field or armature or both circuits. Details of these matters are out of place here; but enough has been said to indicate the desirability of consulting the supply company's engineers before deciding upon the motor to be used.

No matter what drive is used, "for exposures of more than a few minutes in length the telescope cannot be trusted to follow the stars perfectly, owing to changes in the refraction and to the inevitable small outstanding errors of adjustment and it is necessary to guide by hand".[19]

An electric drive lends itself more easily to refined methods of control than those previously discussed, for which the simple hand

[18]Of course in most of the larger electric supply systems such variations of speed are rare.

[19]Russell, Dugan and Stewart, "Astronomy", p. 54.

operated slow motions are most convenient. The method adopted depends upon the motor. For a synchronous motor, some sort of differential gearing and a second motor must be used; a resistance control will serve for the universal motor but for this and the induction type, some form of clock control is the best.

Perhaps the most satisfactory of these is that due to Gerrish of Harvard College Observatory. It is simple and has completely stood the test of the exacting work of celestial photography, while such modifications as are desirable to accomplish particular results can be made without difficulty.

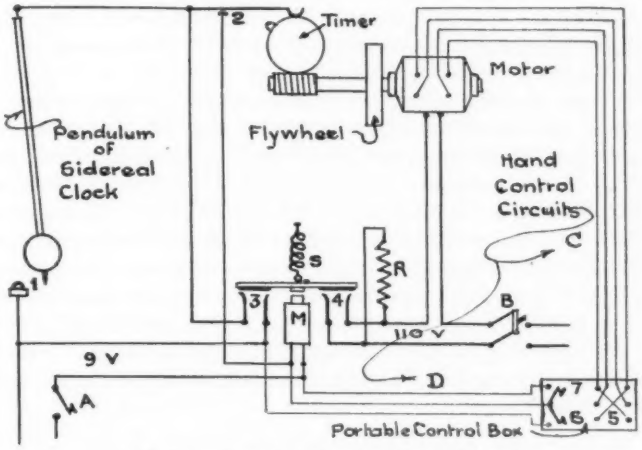

Fig. 18. Circuit of Gerrish Speed Control.

Excluding the circuits marked "hand control", Fig. 18 is a schematic arrangement of this drive. The extended shaft of the main driving motor carries a heavy flywheel and a worm reduction gear driving a timing cam which runs at 60 r.p.m. when the motor is at the selected speed, usually about 10 per cent. below its rated speed. The timing cam operates a switch no. 2 which controls the circuit of the magnet *M*. When energized, this magnet overcomes the pull of the spring *S* and closes switches 3 and 4. Switch 3 shunts the contact maker 1, so keeping the magnet circuit closed

while the contact maker 1 is open. Switch 4 closes the power circuit and allows the motor to start.

Assume the non-existence of the hand control circuits, the motor at rest and all switches open except no. 2. On closing the two main circuit switches *A* and *B* the swinging pendulum closes the contact 1, permitting the 9-volt current to flow via switch 2 and energize the magnet *M* which closes switches 3 and 4. The motor starts, gaining speed until the motion of the timing cam opens switch 2; the magnet *M* releases its armature and the spring *S* pulls open switches 3 and 4.[20]

As the timing cam runs on under the action of the flywheel, it recloses 2. The pendulum in its swing recloses the contact 1 and this series of events repeats so long as the motor runs, energy being supplied to it for a fraction of each second.

Should the speed drop, switch 2 stays closed for longer periods bringing the motor up to speed again, and vice versa. As no current can flow in the power circuit until the pendulum by closing contact 1 causes the magnet to reclose switches 3 and 4, the speed of the motor is at all times under the control of the sidereal clock.

The principal modification of the Gerrish drive is the use of an additional motor and differential gearing to permit of operating the R.A. slow motion by push button control while at the eyepiece.

Fig. 19 illustrates this modification. This figure and the following description is taken, with his kind consent, from Dr. R. K. Young's article on building a 19-in. telescope already mentioned, (see 3 above):

> The main driving motor turns the worm gear *A*, Fig. 19, at 1725 revolutions per minute when running at its normal rate. This gear engages with the timer wheel, as shown in the diagram, which interrupts the current fed to the motor and keeps the timer wheel running at sixty revolutions per minute, thus reducing the motor speed to 1600. The current is flowing for about 0.60 to 0.75 of a second and the balance wheel carries on for the rest of the second. . . .
>
> The driving motor communicates through a differential train of gears to the driving shaft. The normal rate of rotation of the driving shaft is ten revolutions per minute when the differential gear is held; and in order to provide slow motion and guiding motion in right ascension I introduced a second motor to operate the differential gear. The second motor makes 1200 revolutions per minute

[20]In some arrangements a resistance R is placed permanently across the contacts of switch 4. The effect is to prevent the speed of the motor dropping too greatly when the switch is opened and also to reduce sparking at its contacts.

and when running it adds or subtracts from the rate of rotation of the driving shaft according to the direction of its rotation. When running at full speed and subtracting its rate from the clock drive, the driving shaft has a slow rotation forward and when running at full speed in the opposite direction the driving shaft turns at nearly double its normal rate. The same hand switch which operates the declination slow motion operates this motor also, so that the observer, by pressing the suitable button, controls the telescope in right ascension and in declination. A sharp tap on the right ascension button can make the telescope move as small an amount as one-hundredth of a second of time.

Let us return now to the hand control circuits shown in Fig. 18. If the drive motor be of the wound rotor type, it can be reversed by reversing the connections between the armature and field windings. In some motors convenient means are provided for doing this, in others the ends of the field windings and the connections from the collector rings must be brought out from the motor to a special terminal board. By arranging a circuit such as shown at *C*, Fig. 18, between this board and a portable double pole two way switch, marked 5, these changes may be made and the rotation of the motor reversed from a distance.

Next, it will be noted that switch 6 in the circuit marked *D* short-circuits switches 1 and 2, preventing the magnet circuit from opening and releasing switch 4. While 6 is closed the supply of current is continuous and the motor will speed up to its normal rated speed. Switch 7, on the other hand, by short-circuiting the magnet *M*, prevents it from closing switch 4. When 7 is held closed the motor will slow down and finally come to rest. Switches 6 and 7 may be of the push button type and together with 5 may be arranged in a portable control box which may be carried or placed near the hand while at the eyepiece.

This arrangement will not prove as flexible as the differential gearing and two motor method of Fig. 19, but it will be found quite satisfactory in most cases and its cost is much less. The reversing switch 5 cannot be applied to a universal motor. The brushes in these motors are given a large "lead" from the neutral position to ensure sparkless commutation. If the connections were reversed in the manner described above they would be quite wrongly placed for successful operation.

To prevent interference with radio reception all contacts and switches in this device must be provided with adequate filters.

Mr. F. J. Hargreaves, F.R.A.S., for some time chairman of the

Instrument Section of the British Astronomical Association, has devoted much attention to devising inexpensive methods for providing guiding control for a telescope driven by a clock-controlled motor as in the Gerrish drive. In one of these, shown diagrammatically in Fig. 20,[21] a light cork tipped brake *B*, carried on the

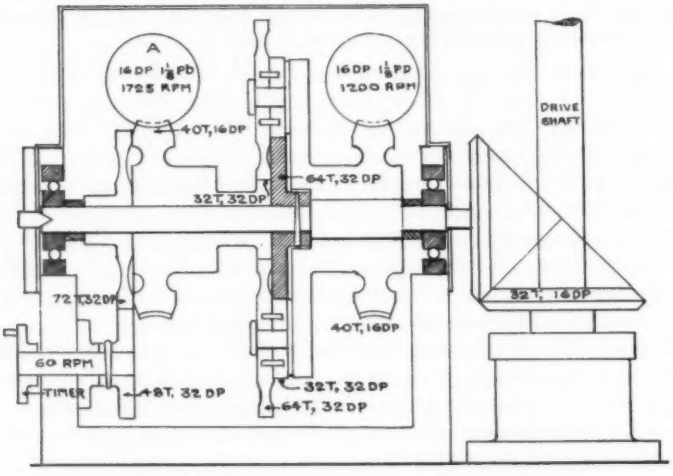

Fig. 19. Section through Electric Clock Gearing.

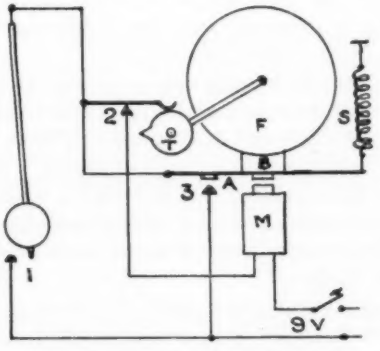

Fig. 20. Hargreaves' Brake Control.

armature *A* of the magnet *M*, is pressed against the flywheel *F* by the spring *S*. The armature also carries a switch contact 3 as in Fig. 18. When the magnet is energized, the brake *B* is released and contact 3 closed and held closed by the magnet until the timer cam *T* on the flywheel shaft opens switch 2. From that point the action is the same as in Fig. 18.

Another and perhaps more convenient device, also due to Hargreaves, is the reversible drive for the slow motion of a differential gear, shown in Fig. 21.

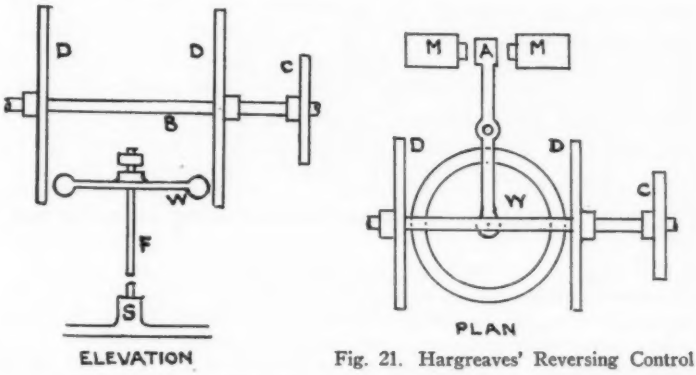

Fig. 21. Hargreaves' Reversing Control

To the turntable spindle *S* of a (synchronous) electric motor of a gramophone, a rubber tired wheel *W* is connected through a thin flexible shaft *F*. A spindle *B* carries two discs *D*, *D*, and electromagnets *M*, *M* attract an armature *A* one way or the other to bring *W* in contact with either disc. A sprocket wheel *C* drives the slow motion shaft of the differential through a light chain. Mr. Hargreaves in a letter says:

> This arrangement works perfectly. I can control the image instantly to 0″.5 or less. During the two years that it has been used it has run itself in and slowly improved in operation. I take photographs of comets, etc., with cameras of 20-in. focal length and find I can leave the telescope driving for an hour at a time, when the pendulum is of the right length. The pendulum however requires adjustment every month or so.

[21]This figure is adapted from the original illustration which appears in *J.B.A.A.*, vol. 41, p. 112.

(*To be continued*)

THE PHYSICAL STATE OF THE UPPER ATMOSPHERE

By B. HAURWITZ

(*Concluded from January issue, page 42*)

X. THE COMPOSITION AND STRUCTURE OF THE ATMOSPHERE

In the preceding chapters various phenomena occurring in the high atmosphere were discussed. There remains only to combine this information into a picture of the composition and structure of the atmosphere.

At the surface the air is mainly a mixture of nitrogen, argon, oxygen and carbon dioxide. Water vapour is also present. It is, however, rather unique in that its amount varies considerably with time and location while the other components occur in almost constant percentages. This difference is due to the fact that, at the temperatures and pressures occurring on the earth, water can exist as solid, liquid and gas. Hydrogen, krypton, xenon, helium and neon have been found in atmospheric air in very small quantities. The following Table VII gives the composition of the air at

TABLE VII. Composition of the air near the surface, after Chapman and Milne

Gas	N_2	O_2	Ar	CO_2	H_2	Ne	He	Xe	Kr
Percentage by weight .	75.5	23.2	1.3	.046 to .4	?	.00086	.000056	.005	.028
Molecular weight	28.0	32.0	39.9	44.0	2.0	20.2	4.0	130.2	82.9

the earth's surface, after Chapman and Milne[113]. Of course, these figures are not invariable, but they give a sufficiently accurate picture of the composition of the air. To give a clearer idea the molecular weights of the different gases have been added. Water vapour has not been included on account of its marked variability. Carbon dioxide likewise varies in amount since it depends on processes at the earth's surface. It has not yet been decided definitely whether or not hydrogen is really present in the atmosphere. The small amounts of hydrogen found in the atmosphere may simply be impurities which unite with oxygen. Therefore, no value for hydrogen has been given in Table VII. Another reason for the assumption that free hydrogen does not exist in the upper atmosphere was given by J. Kaplan[114]. In his experimental reproductions of the spectrum of the aurora and the light of the night

sky he found that hydrogen prevents the appearance of the afterglow with the auroral spectrum when it is present in a discharge tube containing nitrogen and when the discharge is uncondensed.

The apparent absence of hydrogen from the earth's atmosphere raises the question as to whether gases can escape into space or not. The critical velocity c_0 which enables a particle at the surface of a celestial body of radius a and gravitational acceleration g to overcome its attraction is given by

$$c_0 = \sqrt{2ga} \quad \ldots\ldots\ldots\ldots\ldots\ldots (46)$$

The velocity c_0 is that which this particle would obtain if it fell upon the body from infinity. For our earth this critical velocity is 11 km./sec. The Maxwell-Boltzmann law for the velocity distribution of gas molecules shows that there are always molecules present in the atmosphere having the critical and higher velocities. J. H. Jeans[117] has computed how large the mean velocity c of the molecules must be in order that an isothermal atmosphere can be lost into space within a certain time. Table VIII gives a portion of his results.

TABLE VIII. Molecular velocities required to dissipate the atmosphere into space, after Jeans

Time	Sun	Mercury	Earth	Moon
years	km/sec.	km/sec.	km/sec.	km/sec.
10^3	160	1.1	2.9	.61
10^6	140	1.1	2.6	.54
10^9	130	.9	2.3	.48

These figures should be compared with the mean molecular velocities as given in Table IX. The sun can evidently retain its atmosphere. The moon on the other hand must have lost its atmosphere in a relatively short time, which agrees with astronomical evidence. In the atmosphere of the earth a mean molecular velocity of 2.6 km/sec. is required if a gas should dissipate completely into space within a million years. Hydrogen reaches such a velocity at temperatures somewhat higher than 500°K. which

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heavy gases krypton, carbon dioxide and argon must play a very minor part in the composition of the air. Even at the surface of the earth they are present only in small proportions and they must decrease rapidly with elevation because of their great molecular weight. Similarly neon cannot be an important constituent of the atmosphere at any height. There are only traces of it present at the ground, and it is much heavier than helium. Chapman and Milne[113] have computed the pressure, density and composition of the atmosphere under various assumptions with regard to the height where the mixing ceases and diffusion equilibrium sets in. Table X shows the partial densities, the total density and the

TABLE X. Partial densities in gr/cm³ for diffusion level 20 km. and a constant temperature 219°K. after Chapman and Milne

Height	N_2	O_2	Ar	Kr	Xe
20 km.	$6.64 \cdot 10^{-5}$	$2.04 \cdot 10^{-5}$	$1.14 \cdot 10^{-6}$	$2.46 \cdot 10^{-8}$	$4.40 \cdot 10^{-9}$
60 km.	$1.71 \cdot 10^{-7}$	$2.24 \cdot 10^{-8}$	$2.33 \cdot 10^{-10}$	$5.23 \cdot 10^{-16}$	$3.47 \cdot 10^{-21}$
100 km.	$4.72 \cdot 10^{-10}$	$2.68 \cdot 10^{-11}$	$5.30 \cdot 10^{-14}$	$1.38 \cdot 10^{-23}$	....
140 km.	$1.41 \cdot 10^{-12}$	$3.48 \cdot 10^{-14}$	$1.34 \cdot 10^{-17}$	....	....
200 km.	$2.65 \cdot 10^{-16}$	$1.90 \cdot 10^{-15}$	$6.42 \cdot 10^{-23}$	....	....
400 km.	....	....	....	....	....

Height	Ne	He	Total density	Pressure
20 km.....	$7.57 \cdot 10^{-10}$	$4.92 \cdot 10^{-11}$	$8.79 \cdot 10^{-5}$	55.3 mbar
60 km.....	$1.03 \cdot 10^{-11}$	$2.10 \cdot 10^{-11}$	$1.93 \cdot 10^{-7}$	$1.24 \cdot 10^{-1}$
100 km.....	$1.49 \cdot 10^{-13}$	$9.10 \cdot 10^{-12}$	$5.08 \cdot 10^{-10}$	$3.63 \cdot 10^{-4}$
140 km.....	$2.26 \cdot 10^{-15}$	$3.97 \cdot 10^{-12}$	$5.41 \cdot 10^{-12}$	$1.91 \cdot 10^{-5}$
200 km.....	$4.66 \cdot 10^{-18}$	$1.17 \cdot 10^{-12}$	$1.17 \cdot 10^{-12}$	$5.62 \cdot 10^{-6}$
400 km.....	....	$2.31 \cdot 10^{-14}$	$2.31 \cdot 10^{-14}$	$1.05 \cdot 10^{-7}$

total pressure for various heights up to 400 km. on the assumption that diffusion equilibrium begins at 20 km. It should be remembered that these figures are no more reliable than the assumptions upon which they are based, especially the height of the diffusion level. This height may be very much higher, as will be discussed later. Therefore, Table X is merely intended to show by a theoretical example how the lighter gases become more and more preponderant as we come into higher altitudes. Thus, up to 100 km. the total density is essentially the sum of the partial densities of nitrogen and oxygen, and above this level helium becomes rapidly the most important constituent of the air. Table XI shows this in a somewhat different way by giving the percentages in mass of the principal atmospheric gases. It is seen also from this table that above 100 km. helium increases rapidly in importance while

TABLE XI. Mass percentages of the principal atmospheric gases for a diffusion level of 20 km., after Chapman and Milne

Height	Helium	Nitrogen	Oxygen	Argon
20 km.	....	75.5	23.2	1.3
40 km.	....	82.9	16.7	.4
60 km.	0.0	88.3	11.6	.1
80 km.	.1	92.0	7.9	0.0
100 km.	1.7	93.0	5.3	
110 km.	6.1	89.8	4.1	
120 km.	18.4	78.7	2.9	
130 km.	44.2	54.2	1.6	
140 km.	73.4	26.0	.6	
150 km.	90.5	9.3	.2	
200 km.	100.0	0.0	0.0	

the percentage of oxygen decreases more rapidly than that of nitrogen owing to its higher molecular weight. The amount of the other constituents never exceeds .05%, with the exception of carbon dioxide which, however, cannot be important at higher levels on account of its weight.

Chapman and Milne have shown also that up to 100 km. total pressure and density are not greatly influenced by the height at which diffusion begins, but above this altitude the height of the diffusion levels becomes of primary importance. In a similar manner, the presence of hydrogen would greatly alter all computed figures in these heights while it is of little importance below 80 km.

Attempts have been made to compute the height at which diffusion equilibrium begins. Maris[115] studied the time required for diffusion equilibrium to be reached in a completely mixed atmosphere when the mixing stops suddenly. Equilibrium for helium, for instance, would set in above 140 km. in one day, above 120 km. in five days and above 106 km. in fifty days. On the other hand, Maris estimates from observations on meteor trains that the wind at these levels would cause the air above 100 km. to move to lower altitudes once in five to twenty-five days. From such considerations he finds the height of the diffusion level to be between 105 and 120 km. for the different gases in winter, at around 110 km. during the summer night and at around 150 km. during the summer day. These figures which naturally can only be a rough approximation show that the diffusion level might be at much greater heights than was previously assumed.

Computations by Epstein[116] point in the same direction. He found that the helium concentration would be 50% higher than in the state of complete mixing

at the height	200	180	160	140	120	100 km.
after the time	2 min.	26 min.	4.8 hr.	2.8 dys.	34 dys.	1.2 yr.

The fundamental assumptions of Epstein's calculations are quite different from Maris's. Nevertheless, it is seen from his figures that at 100 km. more than a year would be required to increase the helium content by 50% over the amount present in the case of complete mixing.

We have not yet mentioned in this summarizing survey the presence of ozone in the atmosphere. This gas is present, however, only in small quantities and, notwithstanding its great influence upon atmospheric absorption and emission, ozone cannot have an important direct effect upon the vertical density and pressure distribution in the atmosphere. With the rather high molecular weight of 48 it could not diffuse to greater heights than where it is generated so that for this reason alone it will not be important in greater altitudes. Since, however, ozone is a powerful absorber of short-wave solar radiation it influences the vertical pressure and density distribution indirectly by raising the temperature of the atmosphere.

Another possibility which should not be overlooked in a discussion of the composition of the atmosphere is the presence of atomic oxygen in the higher layers (cf. p. 32). In this case the percentage of oxygen in these layers would be higher than with diatomic oxygen owing to its smaller molecular weight of 16.

Thus we finally obtain the following picture of our atmosphere. The lowest 10 km., approximately, constitute the troposphere (Ch. I). Here, the atmospheric gases are thoroughly mixed, the temperature generally decreases with the elevation at the rate of about 5 to 6° C. per 1 km. and water vapour is present in varying quantities which are sufficiently large to condense frequently into clouds which give precipitation. Above the troposphere we have the stratosphere, characterized by the fact that there is in general no temperature change or there may even be a slight increase of the temperature upward. This being a much more stable stratification than in the troposphere, the stirring and mixing of the atmospheric gases must be greatly diminished, as is borne out by Paneth and Glückauf's observation[111] that the percentage of the helium increases at about 20 km. It is, however, not to be expected that mixing stops completely at this level. The observations of meteor trains show that turbulence reaches much higher up. Also, theoretical investigations show that, owing to the slowness with which diffusion equilibrium takes place, due to the rearrangement of the gases by diffusion, an appreciable approach towards the state of diffusion equilibrium is not to be expected below 100 km.

In general, clouds are not observed in the stratosphere. Clouds have appeared, however, at altitudes between 20 and 30 km. on rare occasions, *i.e.*, the mother-of-pearl clouds (Ch. II). The nature of these phenomena is not yet known, but it is not contrary to the present state of our information to regard them as condensation products of water vapour, like the tropospheric clouds. The noctilucent clouds, observed at heights of about 80 km., seem to be of an entirely different origin. They probably consist of meteoric dust which enters the atmosphere at certain times and which is high enough to be illuminated by the sun even during the night.

Ozone is already present in appreciable amount at a height of 20 km. (Ch. VIII). It greatly influences the balance of atmospheric heat. The observations of the anomalous propagation of sound (Ch. IX) indicate a marked temperature increase between 30 and 40 km. which can be attributed to the presence of ozone there. Besides ozone monatomic and diatomic oxygen also might contribute to the rise in temperature at these levels, according to Chapman[118]. Above the layers of maximum ozone content the percentage of atomic oxygen must increase[103]. Diatomic oxygen and ozone are split into atomic oxygen by solar radiation. The formation of diatomic oxygen and ozone, on the other hand, takes place as three-body collision and, evidently, the chance for a three-body collision decreases as the atmosphere becomes rarer. A. K. Das[119] has estimated that at the levels between 100 and 200 km. atomic oxygen might produce temperatures between 1400° and 2900°K. in daytime and between 650° to 1400°K. during the night. These figures should be regarded as very hypothetical, since our knowledge regarding the amount of atomic oxygen and its absorbing power at these altitudes is still very incomplete.

There are, however, other indications that the atmosphere at these altitudes reaches very high temperatures and undergoes considerable temperature changes from day to night. The high altitude of the aurora in the sunlit atmosphere indicates a much greater density during the day than during the night, which is most easily interpreted as caused by a diurnal variation of temperature (cf. p. 399, Dec.). Similarly, a considerable heating of the ionized F_2-layer

is suggested by the absence of an ionization maximum at noon and in summer (cf. p. 356, Nov.).

A characteristic feature of the high atmospheric layers is their electric charge as evidenced by magnetic storms, aurorae (Ch. VII) and reflection and refraction of radio waves (Ch. V). Aurorae and magnetic storms are due to particles emitted by the sun. The nature of these particles is not quite clear yet but at least some of them seem to be electrons. The main part of the electric charge of the high atmosphere, however, is due not to particles coming from the sun but to ionization of the atmospheric gases caused by ultra-violet sunlight. The motion of the ionized layer, under the influence of tidal forces, in the magnetic field of the earth gives rise to the daily variations of the terrestrial magnetism (Ch. VI). The study of this ionized layer by means of the reflection and refraction of radio waves (Ch. V) has revealed a rather complex and varying subdivision into different layers.

The upper atmosphere emits a faint light (Ch. IV). Spectroscopic analysis has shown the presence of lines of oxygen, nitrogen and water vapour in this radiation, but the absence of lines of other gases cannot be regarded as sufficient proof that such gases are not present in the high atmosphere.

LITERATURE

I. *Introduction. Troposphere and Stratosphere*

[1]W. R. Gregg, R. T. Samuels and W. R. Stevens: The meteorology of the free atmosphere. Physics of the earth III, Ch. IV, Bull. Nat. Res. Council, no. 79, Washington 1931.

[2]C. L. Pekeris: The development and present status of the theory of the heat balance in the atmosphere. Mass. Inst. of Technology, Meteorol. course. Prof. Notes no. 5, Cambridge, Mass., 1932.

II. *Some Optical Phenomena, Mother-of-pearl Clouds and Notilucent Clouds*

[3]C. Störmer: Photogrammetrische Bestimmung der Höhe von irisierenden Wolken (Perlmutterwolken) am 30. Dez. 1926. Geofys. Publ., Vol. V, no. 2, pp. 1-8, 1927.

[4]C. Störmer: Höhe und Farbenverteilung der Perlmutterwolken. Geofys. Pub., vol. IX, no. 4, pp. 1-27, 1932.
[5]A. Thomson: Mother-of-pearl clouds. Journ. Roy. Astron. Soc. of Canada, vol. 26, pp. 437-441, 1932.
[6]C. Störmer: Measurements of luminous night clouds in Norway 1933 and 1934. Astrophysica norvegica, vol. I, 3, pp. 87-114, 1935.
[7]E. H. Vestine: Noctilucent clouds. Journ. Roy. Astron. Soc. of Canada, vol. 28, pp. 244-272, 303-317, 1934.
[8]W. J. Humphreys: Nacreous and noctilucent clouds. Monthly Weather Rev., vol. 61, pp. 228-229, 1933.

III. *Meteors*

[9]F. A. Lindemann and G. M. B. Dobson: A theory of meteors and the density and temperature of the outer atmosphere to which it leads. Proc. Roy. Soc. Lond., Ser. A, vol. 102, pp. 441-437, 1922/23.
[10]A. Wegener: Anfangs- und Endhöhen grosser Meteore. Met. Zeitschr., vol. 44, pp. 281-284, 1927.
[11]J. Egedal: On tides of the upper atmosphere. Publ. Danske Met. Inst., no. 10, 1930.
[12]P. M. Millman: An analysis of meteor spectra. Ann. Astron. Obs. Harvard Coll., vol. 82, no. 6, 1932.
[13]P. M. Millman: An analysis of meteor spectra. 2nd paper. Ibid., vol. 82, no. 7, 1935.
[14]H. B. Maris: A theory of meteors. Terr. Magn., vol. 34, pp. 309-316, 1929.
[15]C. M. Sparrow: Physical theory of meteors, Ap. J., vol. LXIII, pp. 90-110, 1926.
[16]E. Öpik: Atomic collisions and radiation of meteors. Acta et comment. Univ. Tartuensis A, vol. XXVI, pp. 1-39, 1934.
[17]C. P. Olivier: Conditions in the upper atmosphere as indicated by a study of meteor trains. Transact. Am. Geophys. Un., pp. 32-34, 1935.

IV. *The Light of the Night Sky*

[18]G. Déjardin: Light of the night sky. Rev. of Mod. Physics, vol. VIII, pp. 1-21, 1936.
[19]J. Dufay: Spectre, couleur et polarisation de la lumière du ciel nocturne. J. de phys. et rad., vol. 10, pp. 219-240, 1929.
[20]E. Wiechert: Polarlichtbeobachtungen in Göttingen. Phys. Zs., vol. 3, pp. 365-366, 1901/02.
[21]H. D. Babcock: A study of the green aurora line by the interferometer method. Ap. J., vol. 57, pp. 209-221, 1923.
[22]J. C. McLennan: The aurora and its spectrum. Proc. Roy. Soc. Lond., Ser. A, vol. 120, pp. 327-357, 1928.

[23]J. KAPLAN: The excitation of the auroral green line by metastable nitrogen molecules. Phys. Rev., vol. 49, pp. 67-69, 1936.

[24]J. DUFAY: Nouvelles observations sur le spectre du ciel nocturne. J. de phys. et rad., vol. 4, pp. 221-235, 1933.

[25]J. CABANNES: Les raies rouges de l'oxygene dans le spectre du ciel nocturne, C.R., vol. 200, pp. 1905-1908, 1935.

[26]J. CABANNES: Sur l'origine des radiations emisès par le ciel nocturne dans l'intervalle spectral, 5000-8000 A. J. de phys. et rad., vol. 5, pp. 601-613, 1934.

[27]LORD RAYLEIGH AND H. S. JONES: The light of the night sky; Analysis of the intensity variations at three stations. Proc. Roy. Soc. Lond., Ser. A, vol. 151, pp. 22-55, 1935.

[28]LORD RAYLEIGH: The light of the night sky III. Proc. Roy. Soc. Lond., Ser. A, vol. 119, pp. 11-33, 1928.

[29]LORD RAYLEIGH: A photoelectric method of measuring the light of the night sky, with studies of the course of variation through the night. Proc. Roy. Soc. Lond., Ser. A, vol. 124, pp. 395-408, 1929.

[30]J. C. MCLENNAN, J. H. MCLEOD AND H. J. C. IRETON: On the intensities of the light of the oxygen green line of the night sky. Trans. Roy. Soc. Can., Sec. III, vol. 22, pp. 397-412, 1928.

[31]J. V. Karandikar: The diurnal variation of the light from the night sky. Ind. Journ. of Phys., vol. VIII., pp. 547-554, 1934.

[32]J. CABANNES: La lumière du ciel nocturne, Helv. Phys. Acta, vol. 8, pp. 405-420, 1935.

[33]S. CHAPMAN: Some phenomena of the upper atmosphere. Proc. Roy. Soc. Lond., Ser. A, vol. 132, pp. 353-374, 1931.

V. *Propagation of Electric Waves and Ionization*

[34]E. V. APPLETON: A new method of measuring upper atmospheric ionization. Nature, vol. 127, p. 197.

[35]E. V. APPLETON AND R. NAISMITH: Some further measurements of the upper atmospheric ionization. Proc. Roy. Soc. Lond., Ser. A, vol. 150, pp. 685-708, 1936.

[36]R. C. COLWELL AND A. W. FRIEND: The D-region of the ionosphere. Nature, vol. 137, p. 782, 1936.

[36a]P. SYAM: The D-layer. Ind. J. of Phys., vol. X, pp. 13-21, 1936.

[37]H. T. STETSON: On the correlation of the radio reception with the moon's position in the observer's sky. Terr. Magn., vol. 36, pp. 1-5, 1931.

[38]L. HARANG: Änderungen der Ionisation der höchsten Atmosphärenschichten während der Nordlichter und erdmagnetischen Störungen. Gerl. Beitr. Geophys., vol. 46, pp. 438-454, 1936.

[39]E. V. APPLETON AND L. INGRAM: Magnetic storms and upper atmospheric ionization. Nature, vol. 136, pp. 548-549, 1935.

[40]L. V. BERKNER: The ionization of the earth's upper atmosphere. Transact. Amer. Geophys. Un., pp. 20-26, 1935.

[40a]D. F. Martyn and O. O. Pulley: The temperatures and constituents of the upper atmosphere. Proc. Roy. Soc. Lond., Ser. A, vol. 154, pp. 455-486, 1936.

[41]S. S. Kirby and E. B. Judson: Recent studies of the ionosphere. Journ. of Res., Nat. Bur. of Stand., vol. 14, pp. 469-486, 1935.

[42]E. O. Hulburt: Theory of the ionosphere. Terr. Magn., vol. 40, pp. 193-200, 1935.

[43]T. H. Johnson: Contribution of the cosmic radiation to the ionization of the upper atmosphere. Transact. Amer. Geophys. Un., pp. 35-37, 1935.

[44]J. T. Henderson: Measurements of ionization in the Kennelly-Heaviside layer during the solar eclipse of 1932. Can. Journ. of Res., vol. 8, pp. 1-36, 1933.

[45]D. C. Rose: Radio observation in the upper ionized layer of the atmosphere at the time of the total solar eclipse of Aug. 31, 1932. Can. Journ. of Res., vol. 8, pp. 15-28, 1933.

[46]S. K. Mitra: Ionospheric studies in India. Nature, vol. 137, pp. 502-503, 1936.

[47]A. M. Skellett: The ionizing effects of meteors. Proc. Inst. Rad. Eng., vol. 23, pp. 132-149, 1935.

[48]S. Chapman: The absorption and dissociative or ionizing effect of monochromatic radiation in an atmosphere on a rotating earth. Proc. Phys. Soc., vol. 43, pp. 26-45, 1931.

[48a]L. V. Berkner, H. W. Wells, and S. L. Seaton: Characteristics of the upper region of the ionosphere. Terr. Magn., vol. 41, pp. 173-184, 1936.

[49]E. A. Milne: Absorption coefficients and the pressure of radiation in the photospheric layer of a star. Monthly Not. Roy. Astr. Soc., vol. 85, p. 768, 1925.

[50]S. Chapman: Ionization in the upper atmosphere. Q. J. Roy. Met. Soc., vol. 52, pp. 225-236, 1926.

[51]A. L. Hughes: On the velocities with which photoelectrons are emitted from matter. Phil. Mag., vol. 25, pp. 683-686, 1913.

[52]J. Fuchs: Eine Radiomethode zur Bestimmung der Absoluttemperatur der Ionosphäre. Met. Zs., vol. 53, pp. 41-44, 1936.

[53]L. V. Berkner and H. W. Wells: F-region ionosphere investigations at low latitudes. Terr. Magn., vol. 39, pp. 215-230, 1934.

VI. *The Diurnal Variations of Terrestrial Magnetism*

[53a]J. Bartels: Terrestrial magnetic activity and its relation to solar phenomena. Terr. Magn., vol. 37, pp. 1-52, 1932.

[54]S. Chapman: On the theory of the solar diurnal variation of the earth magnetism. Proc. Roy. Soc. Lond., Ser. A, vol. 122, pp. 369-386, 1929.

[55]O. Pedersen: The propagation of the radio waves, Copenhagen, 1927.

[56]T. G. Cowling: On the radial limitations of the sun's magnetic field. Monthly Not. R. Astr. Soc. Lond., vol. 90, pp. 140-154, 1929.

[57]Ross Gunn: The diamagnetic layer of the earth's atmosphere and its relation to the diurnal variation of terrestrial magnetism. Phys. Rev., vol. 32, pp. 133-141, 1928.

[58]S. Chapman: The solar and lunar diurnal variations of terrestrial magnetism Phil. Trans. Roy. Soc. Lond., Ser. A, vol. 218, pp. 1-118, 1919.

[59]S. Chapman: The lunar diurnal magnetic variation at Greenwich and other observatories. Phil. Transact. Roy. Soc. Lond., Ser. A, vol. 225, pp. 49-91, 1925.

[59a]J. Bartels: Die höchsten Atmosphärenschichten. Erg. exakt. Nat.-Wiss., vol. 7, pp. 114-157, Berlin 1928.

VII. *The Aurora*

[60]Photographic atlas of auroral forms and scheme for visual observations of aurorae. Oslo, 1930. Also Jour. R. Ast. Soc. Can., vol. 23, p. 1, 1929.

[61]F. T. Davies: Observations of the aurora australis, Byrd Antarctic expedition, 1929. Terr. Magn., vol. 36, pp. 199-230, 1931.

[62]C. Störmer: Über die Probleme des Polarlichtes. Erg. der kosm. Phys., vol. I, pp. 1-86, Leipzig, 1931.

[63]T. Alty and F. J. Wilson: Height of the aurora in Canada. Nature, vol. 133, pp. 687-688, 1934.

[64]B. W. Currie: Summary of some auroral height measurements and observations at Chesterfield, Canada. Terr. Magn., vol. 39, pp. 293-297, 1934.

[65]J. C. McLennan, H. S. Wynne-Edwards and H. J. C. Ireton: Height of the polar aurora in Canada. Can. Journ. of Res., vol. 5, pp. 285-296, 1931.

[66]C. Störmer: Twenty-five years work on the polar aurora. Terr. Magn., vol. 35, pp. 193-208, 1930.

[67]L. Vegard and E. Tönsberg: Enhancement of red lines and bands in the auroral spectrum from a sunlit atmosphere. Nature, vol. 137, pp. 778-779, 1936.

[68]L. Vegard: The temperature of the auroral region determined by the rotational series of the negative N-bands. Terr. Magn., vol. 37, pp. 389-398, 1932.

[69]L. Vegard: On the determination of temperature by means of band spectra. Norske Vid.-Ak. Avh. I, no. 12, 1934.

[70]L. Vegard: The aurora and night sky spectra and the upper atmosphere. Transact. Am. Geophys. Un., part I, pp. 38-40, 1935.

[71]L. Vegard, H. Th. Ringsdal and A. Benedicks: Determination of the temperature by means of bands taken with spectrographs of small dispersion. Norske Vid.-Ak. Avh. I, no. 13, 1934.

[72]S. Rosseland and G. Steensholt: On the relative intensity of bands in a sequence and the temperature of the upper atmosphere. Norske Vid.-Ak. Avh. I, no. 5, 1933.

[73]G. Angenheister: Die Höhe der Polarlichter und die Temperatur der oberen Atmosphäre. Terr. Magn., vol. 37, pp. 431-438, 1932.

[73a]L. HARANG: Vertical movements of the air in the upper atmosphere. Terr. Magn., vol. 41, pp. 143-160, 1936.

[74]L. VEGARD: Die sonnenbelichteten Nordlichtstrahlen und die Konstitution der höheren Atmosphärenschichten. Zs. f. Geophys., vol. VI, pp. 42-56, 1930.

[75]C. STÖRMER: Sur le mouvement d'un point matériel portant une charge d'électricité sous l'action d'un aimant élémentaire. Videnskabsselsk. Skrifter, no. 3, Christiana 1904.

[76]L. VEGARD AND O. KROGNESS: The position in space of the aurora polaris. Geofys. Publ. I, 1, Oslo, 1920.

[77]E. BRÜCHE: Some new theoretical and experimental results on the aurora polaris. Terr. Magn., vol. 36, pp. 41-52, 1931.

[78]C. STÖRMER: How the horse-shoe formed auroral curtains can be explained by the corpuscular theory. Terr. Magn., vol. 37, pp. 375-388, 1932.

[79]C. STÖRMER: Kurzwellenechos, die mehrere Sekunden nach dem Hauptsignal eintreffen, und wie sie sich aus der Theorie der Polarlichter erklären lassen. Naturwissenschaften, vol. 17, pp. 643-651, 1929.

[80]S. CHAPMAN AND V. C. FERRARO: Electric state of the solar streams of corpuscles. M. Not. Roy. Astr. Soc. Lond., vol. 89, pp. 470-479, 1929.

[81]S. CHAPMAN AND V. C. FERRARO: A new theory of magnetic storms. Terr. Magn., vol. 36, pp. 77-97, 171-186, 1931; vol. 37, pp. 421-429, 1932; vol. 38, pp. 79-96, 1933.

[82]E. A. MILNE: On the possibility of the emission of high-speed atoms from the sun and stars. M. Not. Roy. Astr. Soc. Lond., vol. 86, pp. 459-473, 1926.

[82a]H. B. MARIS AND E. O. HULBURT: A theory of auroras and magnetic storms. Phys. Rev., vol. 33, pp. 412-431, 1929.

[82b]S. CHAPMAN: On the solar ultra-violet radiation as the cause of aurorae and magnetic storms. Monthly Not. Roy. Astr. Soc. Lond. Geophys. Suppl., vol. 2, pp. 296-300, 1930.

VIII. *Ozone*

[83]M. LAMBREY ET D. CHALONGE: Structure de la bande d'absorption ultraviolette de l'ozone. Gerl. Beitr. Geophys., vol. 24, pp. 42-48, 1929/1930.

[84]F. LINDHOLM: Note sur l'absorption de l'ozone dans la partie infrarouge du spectre solaire. Gerl. Beitr. Geophys., vol. 24, pp. 53-58, 1929/1930.

[85]CH. FABRY: The absorption of the radiation in the upper atmosphere. Proc. Phys. Soc. Lond., vol. 39, pp. 1-14, 1927.

[86]CH. FABRY ET M. BUISSON: Etude de l'extremité ultraviolette du spectre solaire. Journ. Phys. et Rad., vol. 2, pp. 197-226, 1921.

[87]P. GÖTZ: Das atmosphärische Ozon. Ergebnisse der kosmischen Physik, Bd. I, pp. 131-235, Leipzig, 1931.

[88]S. ROSSELAND: A theoretical remark on the distribution of ozone in the atmosphere. Gerl. Beitr. z. Geophys., vol. 24, pp. 50-52, 1929/30.

[89]J. CABANNES ET DUFAY: Mesure de l'altitude et de l'épaisseur de la couche d'ozone dans l'atmosphère. J. Phys. et Rad. (6), vol. 8, pp. 125-152, 1927.

[90]F. W. P. Götz, A. R. Meetham and G. M. B. Dobson: The vertical distribution of ozone in the atmosphere. Proc. Roy. Soc. Lond., Ser. A, vol. 145, pp. 416-446, 1934.

[91]F. W. P. Götz: Zum Strahlungsklima des Spitzbergensommers. Strahlungs-sund Ozonmessungen in der Königsbucht 1929. Gerl. Beitr. z. Geophys., vol. 31, pp. 119-154, 1931.

[92]S. Chapman: The Götz-inversion of intensity ratio in zenith scattered sunlight. Phil. Transact. Roy. Soc. Lond., Ser. A, vol. 234, pp. 205-230, 1935.

[93]G. M. B. Dobson, D. N. Harrison and J. Lawrence: Measurements of the amount of ozone in the earth's atmosphere and its relation to other geophysical conditions, Part. III. Proc. Roy. Soc. Lond., Ser. A, vol. 122, pp. 456-486, 1928.

[94]G. M. B. Dobson: Observations of the amount of ozone in the earth's atmosphere and its relations to other geophysical conditions, Part. IV, with reports by H. H. Kimball and L. Kidson. Proc. Roy. Soc. Lond., Ser. A, vol. 129, pp. 411-433, 1930.

[95]P. Duckert: Messungen des Ozongehaltes über Lindenberg. Beitr. z. Phys. d. fr. Atmosph., vol. 14, pp. 219-239, 1928.

[96]V. Bjerknes: Sur les relations entre l'ozone et les mouvements de la troposphère. Gerl. Beitr. z. Geophys., vol. 24, p. 65, 1929/30.

[97]F. W. P. Götz and G. M. B. Dobson: Observations of the height of the ozone in the upper atmosphere, Part I. Proc. Roy. Soc. Lond., Ser. A, vol. 120, pp. 251-259, 1928; Part. II, vol. 125, pp. 292-294, 1929.

[98]A. R. Meetham and G. M. B. Dobson: The vertical distribution of atmospheric ozone in high latitudes. Proc. Roy. Soc. Lond., Ser. A, vol. 148, pp. 598-603, 1935.

[99]E. Regener und V. H. Regener: Aufnahmen des ultravioletten Sonnenspektrums in der Stratosphäre und die vertikale Ozonverteilung. Phys. Zs., vol. 35, pp. 788-793, 1934.

[100]E. H. Gowan: The effect of ozone on the temperature of the upper atmosphere. Proc. Roy. Soc. Lond., Ser. A, vol. 120, pp. 655-669, 1928; Part. II, vol. 128, pp. 531-580, 1930.

[101]S. Chapman: A theory of upper atmospheric ozone. Mem. Roy. Met. Soc., vol. III, no. 26, 1929.

[102]S. Chapman: On the annual variation of upper atmospheric ozone. Phil. Mag., Ser. 7, vol. 10, pp. 345-352, 1930.

[103]S. Chapman: On ozone and atomic oxygen in the upper atmosphere. Ibid., vol. 10, pp. 369-383, 1930.

IX. *Anomalous Propagation of Sound*

[104]W. S. Tucker: Meteorological acoustics. Q. Journ. Roy. Met. Soc., vol. 59, pp. 203-216, 1933.

[105]F. J. W. Whipple: The propagation of sound waves to great distances. Q.

Journ. Roy. Met. Soc., vol. 61, pp. 285-308, 1935.

[106]P. DUCKERT: Ueber die Ausbreitung von Explosionswellen in der Erdatmosphäre. Erg. d. kosm. Phys., vol. I, pp. 236-290, Leipzig, 1931.

[107]H. GALBRUN: Propagation d'une onde sonore dans l'atmosphère et théorie des zones de silence. Paris, 1931.

[108]O. MEISSER: Luftseismik. Handbuch der Experimentalphysik, Bd. 25, III, Kap. 1, pp. 228-241, 1930.

[109]E. WIECHERT: Bemerkungen über die anomale Schallausbreitung in der Luft. 2. and 3. Mitteilung. Nachr. Ges. Wiss. Gött. Math.-Nat. Kl. 1926, pp. 93-103, 201-211.

[110]K. WÖLCKEN: Schalluntersuchungen im Polargebiet. Zs. f. Geophys., vol. 10, pp. 222-234, 1934.

X. *The Composition and Structure of the Atmosphere*

[111]E. A. PANETH AND E. GLÜCKAUF: Helium content of the stratosphere. Nature, vol. 136, p. 717, 1935.

[112]L. H. G. DINES: A form of apparatus for obtaining samples of the atmosphere from great heights. Q. Journ. Roy. Met. Soc., vol. 62, pp. 379-386, 1936.

[113]S. CHAPMAN AND E. A. MILNE: The composition, ionisation and viscosity of the atmosphere at great heights. Q. Journ. Roy. Met. Soc., vol. 46, pp. 357-396, 1920.

[114]J. KAPLAN: Hydrogen in the upper atmosphere. Nature, vol. 136, pp. 549-550, 1935.

[115]H. B. MARIS: The upper atmosphere. Terr. Magn., vol. 33, pp. 233-255, 1928; vol. 34, pp. 45-53, 1929.

[116]P. S. EPSTEIN: Ueber Gasentmischung in der Atmosphäre. Gerl. Beitr. z. Geophys., vol. 35, pp. 153-165, 1932.

[117]J. H. JEANS: Dynamic theory of gases, 3rd edition, p. 346, Cambridge, 1921.

[118]S. CHAPMAN: The gases of the atmosphere. Q. Journ. Roy. Met. Soc., vol. 60, pp. 127-142, 1934.

[119]A. K. DAS: On the temperature of the earth's outer atmosphere and the forbidden OI lines of the night sky spectrum. Gerl. Beitr. z. Geophys., vol. 47, pp. 136-148, 1936.

[120]H. JEFFREYS: The earth. 2nd edition, p. 219, Cambridge, 1929.

[121]R. EMDEN: Thermodynamik der Himmelskörper in Encyklopädie d. math. Wissenschaften VI, 2, 24, p. 402, 1926.

Meteorological Office
Toronto, Canada
July, 1936

METEOR NEWS

Observations relating to meteors and meteorites are cordially invited.

A Call for Volunteers to Observe Telescopic Meteors

A programme for international co-operation in the observation of telescopic meteors has recently been announced by the Sternberg Astronomical Institute of the University of Moscow. The observation of such meteors is very important in the discussion of almost all the major problems confronting the astronomer in the field of meteoric research and especially in connection with our estimates of the total mass of meteoric matter existing in interstellar space. The present programme is under the immediate direction of the Comet and Meteor Section of the Sternberg Institute. The chairman of this section is Dr. S. Orlov; the secretary, Dr. I. Astapowitsch. The latter has already carried out a fairly extensive investigation of telescopic meteors and so is well qualified to plan observational programmes for the future.

The writer would like to point out to members of the Society that this programme offers an excellent opportunity for those with small telescopes or prism binoculars to co-operate in some really worth-while astronomical research. Observations sent in to this department of the Journal will be forwarded to Moscow where the combined results from all countries will be published. This effort to learn more about the very faint meteors has the full support of the International Astronomical Union and it would be a fine thing if a number of really active observers could be found in Canada.

The instructions for observers will be found below, and should any questions arise the writer will be glad to attempt to answer them. The most efficient type of telescope to use in this work is one with an aperture between 2 and 6 inches, equipped with a very low power and having a wide field of view, such as the modern comet seeker. Lacking such a telescope one might use a good pair of prism binoculars equipped with a firm mounting. Observations should be made from 11.00 p.m. to 1.00 a.m. local mean time on any or all of the nights listed, with the telescope centered on the region or star indicated in the following table. The average number of

telescopic meteors to be expected in one observing period is from 2 to 5 and reports of all observations carried out should be sent in whether meteors are seen or not. This last point is particularly important.

NIGHTS FOR TELESCOPIC METEOR OBSERVATION
(International Programme for 1937)

Date (1937)	Regions A	Date (1937)	Regions B			
Jan. 12/13....	Zenith	Jan. 13/14.....	ιGem	α 7^h	20^m	δ+28°
Feb. 11/12....	"	Feb. 12/13.....	oLeo	9	35	+10
Mar. 11/12....	"	Mar. 12/13.....	τLeo	11	20	+4
Apr. 19/20....	"	Apr. 20/21.....	κLyr	18	15	+36
May 10/11....	"	May 11/12.....	ζLib	15	25	−17
June 8/9.....	"	June 9/10.....	ξOph	17	15	−21
July 8/9.....	"	July 9/10.....	dSag	19	10	−19
Aug. 9/10....	"	Aug. 10/11.....	ηPer	2	40	+55
Sept. 6/7.....	"	Sept. 7/8.....	σAqu	22	25	−12
Oct. 8/9.....	"	Oct. 9/10.....	ηAri	2	05	+21
Nov. 15/16....	"	Nov. 16/17.....	πAri	2	40	+17
Dec. 10/11....	"	Dec. 11/12.....	πGem	7	40	+34

The following information should be listed on the record sheets:
Observer's name—
Observing station—latitude, longitude, altitude.
Instrument—aperture, magnification, diameter of field.
Time of observation—beginning, end, interruptions.
Weather conditions, etc.—
Data concerning each meteor:

—time to nearest 0.1 min.
—maximum brightness compared with naked eye stars to nearest 0.5 mag.
—length of path or parts of this observed, in minutes of arc.
—duration, estimated to nearest 0.1 sec. if possible.
—direction of flight, given as position angle counted from north through east up to 360 deg. when observing regions A; given by plotting the meteor trail on a chart of the stars visible in the field when observing regions B.
—remarks concerning colour, train duration and any other interesting details.

Observations of the Leonoids in 1936

Visual and photographic observations of the 1936 Leonid shower were planned in Ontario for the nights near the maximum, but very poor weather conditions at this time resulted in meagre reports from the various stations. The groups which were able to make some observations are listed below.

Leonid Observation Groups, 1936

1. *Dunlap Observatory, Richmond Hill, Ont.*: A. Adamson, V. L. Davis, M. Dudley, H. H. Footit, T. A. Goulding, P. M. Millman, C. Pearce.
2. *Dominion Observatory, Ottawa, Ont.*: F. Beasley, W. D. McLennan, M. M. Thomson.
3. *London, Ont.*: J. C. Higgins, Prof. H. R. Kingston, J. Middlebrook.
4. *Orillia, Ont.*: Jack Grant.

The number of meteors observed at the various stations will be found in Table I. The last column in this table gives the hourly rate reduced to six observers. The most reliable rate is that for the 50 minutes of clear sky at the Dunlap Observatory. At Ottawa and

Table I

Group	Date	E.S.T.	Average number of observers	Meteors observed		Reduced hourly rates	
				L	NL	L	NL
1.....	Nov. 16-17	2.10–3.00	4	11	20	15	27
		3.00–4.30	3	10*	5	14*	7
2.....	Nov. 16-17			2*	2		
	17-18	3.10–4.30	1	7	2	20	6
3.....	Nov. 16-17	12.50–1.50	2	1	4		
		2.15–3.15	2	2	5		
4.....	Nov. 15-18			2*	1		
			Totals.....	35	39		

*Clouds

Orillia the visual observers had to look after cameras for the greater part of the time and so could only plot occasional meteors. As far as can be judged from the scanty data in Table I the Leonids at their 1936 maximum were not much more than half as numerous as in the last three years (see Meteor News for January, 1936). It is interesting to note that, during the last five years, the frequency of Leonids appearing over a day away from the time of maximum has not varied appreciably. The major part of the variation in rates has been on the maximum night.

Photographic observations were carried out at most of the above stations but no meteors were photographed. The equipment used was the same as that employed for the Perseid observations which were reported last month except that in this case rotating shutters were used at both Ottawa and Richmond Hill. The total number of hours exposed is listed in Table II, some clouds being present

TABLE II

Station	Date	Total Exposure
Spectrophotography		
Richmond Hill, Ont.	Nov. 16-17	4.3 hrs.
Direct Photography		
Richmond Hill, Ont.	Nov. 16-17	1.8
Ottawa, Ont.	16-18	3.6
Hull, Que.	16-17	1.8
Orillia, Ont.	15-18	10.6

during approximately half the time the cameras were used. Mr. Grant in Orillia had the best luck with the weather as he was able to make exposures on three nights.

Judging from the results of the Leonid observations of the past few years we are now apparently well past the time when excessive numbers of Leonids are a possibility. Thanks are due those who did what they could in carrying out a study of the Leonids in spite of adverse weather conditions.

P. M. M.

REVIEW OF PUBLICATIONS

The Moon with Naked Eye and Field Glasses, by Calvin N. Joyner. 135 pp. 7½×10½ inches, Tientsin, Oriental Bookstore, 1936. Price postpaid, $2.00 (Canadian).

The author, a diligent amateur working in China with a twelve-inch reflector, has prepared this book to serve as an introduction to the study of the topography of the moon. The book may be considered as consisting of three fairly distinct parts: (1) eleven photographs, with key charts, of the moon at various phases, (2) half a dozen very brief descriptive chapters dealing with the appearance of some of the most notable objects, and (3) a large folding lunar map, with a catalogue of 300 of the most striking lunar formations.

The photographs were made by the author, and are printed reversed, so as to correspond to the appearance of the moon to the unaided eye, in field glasses or in a terrestrial telescope. There is a considerable variation in the quality of these plates, apparently partly attributable to the process of reproduction. The text is concerned with description of the features, and omits or only briefly mentions many of the modern researches and ideas as to the nature and origin of the different types of markings. The author's hypothetical traveller to the moon apparently has some difficulty in keeping his orientation correct.

Undoubtedly the most useful part of the book is the table of lunar formations, which gives, as well as the position on the map, the nature and size of each feature. Most of this material is based on Goodacre's work. The 30-inch map is unnecessarily large for a map showing such a small number of details. A map a few inches across, printed on cardboard, would seem to be much more useful for an observer wishing to identify lunar formations.

The author is to be congratulated on his systematic study of the moon's features, and the freedom of his work from serious errors. The book should fulfil its purpose as "a guide book for casual visitors to the moon."

F. S. H.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

What Kind of Universe is It?

On January 5, in Washington, Dr. E. P. Hubble of the Mount Wilson Observatory lectured on "Our Sample of the Universe," and gave the results of studies with the 100-inch refractor, by means of which the observable portion of our universe is stated to be a sphere with a radius of 400 million light-years. An outline of the lecture is given by *Science Service,* as follows:

Studies so far made seem to present a choice of two kinds of universe: (1) a small expanding universe which is finite in extent but unbounded, and (2) a universe indefinitely large that is not expanding appreciably but which contains some unknown principle of nature. The explanation chosen to account for the observed reddening of the light from the most distant nebulae fixes the choice of these two alternate points of view. If the reddening, or so-called red-shift, is considered due to the expansion of the universe, then a curvature in space has to be brought into the picture to account for the observed density distribution. Otherwise the density of distribution would increase outward systematically in all directions and our own stellar system would be left in a unique position. At the present time, the curvature is positive and very large, so that if the red-shifts measure expansion, then the universe is finite in size and very small. In fact the present radius of spatial curvature would be just less than the present penetrating power of the 100-inch reflector.

Of the alternate concept of the size of the universe, Dr. Hubble indicated that if the red-shift is not due to expansion but to some yet unknown principle of nature which does not involve actual motion, then the true distribution of nebulae is sensibly uniform. And since the observable region is homogeneous, the universe, presumably, is so vastly greater than the observed sample that no positive inferences can be drawn. Thus a choice is offered between a small expanding universe and a universe of immense but unknown dimensions plus a new principle of nature. It is possible that the theory (the expanding universe postulated by Abbé Lemaitre) may be generalized to include new models. Otherwise, the probabilities, at the moment, seem to favour the greater universe, although a definite choice will doubtless await more powerful methods or still greater telescopes.

A World Famous Journal

It was in 1895 that George E. Hale and James E. Keeler founded *The Astrophysical Journal,* which is just beginning its 85th volume.

From its first issue, this magazine has been produced in superior style and it has possessed a certain austere dignity. It is almost indispensable to the working astronomer. The editors are just starting the publication of a series of authoritative monographs on astronomical subjects and incidentally they would like to increase the number of their subscribers. The following announcement is published with pleasure:

The Editors of *The Astrophysical Journal* wish to announce the beginning of a new series of *Astrophysical Monographs* which will form a gradually expanding library of modern astrophysics. Each monograph will be an exhaustive summary of a limited field of knowledge intended not only as a reference volume for investigators but also as a manual for teachers and advanced students. The first two monographs will be issued early in 1937: *The Masses of the Stars* by Professor Henry Norris Russell, of Princeton University, and *Methods and Results of Statistical Investigations Concerning Stellar Distribution* by Professor Bart J. Bok of Harvard University. Arrangements are under way for a monograph on the spectra of variable stars by Dr. P. W. Merrill of the Mount Wilson Observatory. Other issues will contain summarizing articles on the formation of absorption lines in stellar spectra, interstellar absorption, problems of stellar constitution and evolution, galactic star clusters, double stars, fundamental stellar photometry, etc. The University of Chicago Press (5750 Ellis Avenue, Chicago, Illinois), which is publishing the monographs on a non-profit basis, wishes to make them available to individual workers and is therefore inviting advance subscriptions on one of three plans: A. To new subscribers to the Astrophysical Journal: half a year's subscription to The Astrophysical Journal, plus two monographs, for $5.00. B. To old or new yearly subscribers to The Astrophysical Journal who order the monographs separately: $1.75 for each of the two monographs. C. To non-subscribers who order only the monographs: $2.00 each. The final published price of the two monographs will be $2.50 each.

A Catalogue of Simple Instruments

Recently there arrived a 16-page catalogue of "simple, practical, inexpensive instruments" designed and constructed by Rev. W. G. Colgrove, M.A., 2 Christie St., London, Ont., which amateurs and instructors will find interesting. Mr. Colgrove has devoted much thought and has shown much ingenuity in the production of these models, which will assist in supplying a clear idea of various celestial phenomena.

C. A. C.

MEETINGS OF THE SOCIETY

AT VICTORIA

October 26, 1936.—A regular meeting was held in the Y.W.C.A. lecture hall. President Tingley occupied the chair. The following were elected to membership: W. A. Thorn, B.Sc., Dr. J. A. Correll, and Kenneth O. Wright, M.A. (Transferred to Victoria Centre).

Mr. J. R. Kerry gave a short talk on some personal experiences with the so-called "death ray" and referred to instances of its use at the present time. Mr. Kerry speculated on the possibility of its being used in the future for astronomical purposes.

Mr. Robert Peters, vice-president of the Centre, was then called upon for his address on "Sir William Herschel, the Father of Astrophysics". After introducing his remarks by tributes to Herschel's father and sister Caroline, Mr. Peters described Sir William Herschel's early manhood,—his study of music, playing the oboe and the violin; his becoming a soldier, joining the guards; and his mastery of several languages. Through his study of music and sound Herschel was led to mathematics, thence to optics which brought his attention to the desirability of possessing a telescope. The price of purchase being prohibitory, he set to work on the construction of one. The speaker vividly portrayed Herschel's industry,—how he turned his home into a veritable workshop and would rush home after playing at a concert to work on the grinding of his speculum and lenses. Herschel was the first to measure the height of lunar mountains. On the 13th of March, 1781, he discovered the planet Uranus. He at first thought it to be a comet, but it was a planet, the first to be discovered since the earliest written records of history. Herschel wanted to name the planet after King George, but at the suggestion of Bode, the name Uranus was finally accepted. Besides making about 80 large telescopes, one a forty-foot-long reflector, Herschel is credited with the discovery of 1,000 double stars, two satellites of Uranus, two of Saturn's satellites and the cataloguing of about 5,000 star clusters and nebulae. He was the first to suggest that our sun was travelling towards a point in Hercules. In this he was very nearly in agreement with the calculations of present day science. His theory that the moon was inhabited and possessed active volcanoes has been, of course, discredited. Herschel lived to the ripe old age of 82.

November 16, 1936.—President Tingley was in the chair. Mr. H. A. Young was called upon for a short paper on an original theory of the moon's rotation.

In introducing Mr. W. A. Thorn, M.A., the speaker of the evening, the president recalled that Herschel was the first to suggest that simultaneous weather observations be made in various parts of the world and that Halley

made the first weather map, so that meteorology in its inception was closely allied with astronomy. "Charting Atmospheric Currents", was Mr. Thorn's subject. Using about fifty photographic slides, the majority of which were charts of air currents, Mr. Thorn showed the connection between meteorology and astronomy. He spoke of the problem of measuring the sun's radiation and the mysterious cosmic rays coming from all directions in space; the various ice-ages and climatic changes, for the explanation of which the astronomer must be consulted; the popular notion of the moon's effect on the weather, in which connection the speaker said that only a very slight tidal effect was due to the moon, but too insignificant to be responsible for the farmer's troubles.

Atmospheric currents were likened to a great thermal engine. The general circulation of the air in the upper levels was pictured, Mr. Thorn telling how information concerning this had been gained through the release of small balloons. He also discussed monsoons, the origin of fogs, and the shielding effect of the Rocky Mountains on the western part of British Columbia, which, because of the mountain barrier, was protected from the cold flow of air from the Yukon and northern Alberta.

GORDON SHAW, *Secretary.*

THE SUMMER COURSE AT VICTORIA

The various centres of our Society throughout Canada may be interested to know of the Victoria Centre's experience with a Summer Course in Astronomy. Inaugurated several summers ago by Mr. H. Boyd Brydon with some half-dozen members, the interest has grown yearly until this last summer. The 1936 course was advertised in the newspapers and over the radio as "A Series of Summer Evenings with the Stars", and brought in many new recruits to the ranks of amateur astronomy. Seven weekly meetings were held with six lectures as follows:

July 13, Dr. R. M. PETRIE, Summer Stars and How to Know Them.
July 20, Miss PHOEBE RIDDLE, B.A., The Moon's Story.
Aug. 3, ROBERT PETERS, Jupiter and His Satellites.
Aug. 10, JAMES DUFF, M.A., Comets and Shooting Stars.
Aug. 17, WILLIAM R. HOBDAY, Solar and Lunar Eclipses.
Aug. 24, Dr. A. MCKELLAR, The Milky Way.

On July 27, the group was taken by chartered buses to the Dominion Astrophysical Observatory, where through the kindness of Dr. W. E. Harper, Director, an opportunity to view the heavens through the 72-inch reflector was enjoyed.

The weekly lectures, which were held at Victoria College, on a high point in the city, were purposely made as simple as possible and were limited to 45 minutes. After the lecture several groups were formed outdoors around telescopes (mostly made by amateurs) and were shown interesting objects such as Jupiter, the moon, double stars, clusters, and nebulae. Added interest

on under Dr. Millman's supervision. Besides the taking of actual observations, the care and adjustment of the instruments takes considerable time.

The regular business of the meeting was postponed until the following meeting, the remainder of the evening being spent inspecting the observatory. The measuring room was open and a exhibit of meteor trails, cameras, and spectra was on display in the computing room. The 19-inch in the south dome of the Administration Building and also the 74-inch were set on Saturn, while a 4½-inch refractor on the lawn was used to view several interesting objects. The evening ended with refreshments.

November 3, 1936.—The regular meeting was held in the McLennan Laboratory, University of Toronto, Mr. E. J. A. Kennedy, vice-chairman, in the chair.

The following were elected members:

Mr. S. K. Dalzell, Toronto
Mr. Adam F. Smith, Toronto
Mr. Neil McNabb, Aston
Mr. O. Kilburn, St. Thomas
Mr. J. C. Mabee, Gananoque
Miss M. M. Melrose, Windsor
Mr. Donald A. MacRae, Toronto
Mr. W. Inrig, Toronto
Col. W. E. Phillips, Oshawa

The assistant librarian gave a report of the periodicals received during the month of October and read a list of the recent popular books which could be obtained at the meeting.

Dr. P. M. Millman, of the David Dunlap Observatory, gave the paper of the evening. It was on "Some Recent Advances in our Knowledge of Shooting Stars", and was mainly a review of the meteor programme carried out at Flagstaff, Arizona, under the guidance of Dr. E. Öpik, of Tartu, Esthonia, and Dr. S. L. Boothroyd of Cornell University. The two years' programme yielded data for 22,000 different meteors, from which it is hoped that definite statistical values of the direction and magnitudes of the motions of meteoric matter can be obtained; perhaps, also, something may be learned of their cosmical origin.

All visual observations were made through reticules at the ends of a 22-mile base-line. Speeds were obtained by using a rocking mirror and a telescope. From results obtained so far, it has been found that the number of meteors belonging to the solar system is considerably fewer than was formerly conceived. Also from the determination of heights, information has been gleaned that is definitely inconsistent with that theory which demanded a hydrogen atmosphere at great heights.

A discussion followed the lecture. The Society regretted to hear that Mr. Maybee was ill, but hoped that his recovery would be so rapid that the position of treasurer need only be filled temporarily by some one else.

The position of the phenomena in the HANDBOOK was pointed out, and attention was drawn to the conjunction of Venus and Jupiter on Friday, November 13.

F. SHIRLEY PATTERSON, *Recorder.*

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